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THE EFFECTS OF STUDENT-GENERATED ELABORATION DURING ACQUISITION OF CONCEPTS IN SCIENCE

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Student-supplied elaboration, in the form of paraphrasing, drawing illustrations, or thinking of verbal analogies for verbally described concepts in the lesson, was less effective during initial acquisition than the experimenter-supplied graphic analogies, and no more effective than using the same amount of time to go through the lesson twice. However, drawing illustrations of concepts in the lesson was the most effective of these elaboration strategies for students with little or no prior knowledge of the subject matter.

After acquisition coding has occurred, the most effective strategy investigated in these studies was a postlesson review in which students were required to reconstruct the complete graphic illustration of the electrochemistry of a battery, by touching appropriate spots on the display screen. This review may have forced the students to do processing that integrated the various electrochemical concepts. Attempts to induce students to review the lesson by generating mental imagery in which they visualized the flow of events in a battery was not an effective review strategy.

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SUMMARY

This is the last of a series of studies of experimenter and student supplied cognitive strategies for acquisition and retention of concepts in science. A lesson in electrochemistry was used as the subject matter in these studies. The conclusions we believe are warranted by the results of these studies as follows. The most effective strategy for facilitating acquisition consisted of experimenter-supplied, interactive graphic analogies that supplemented verbal description, in comparison to additional verbal explanation. Two explanations for these positive effects would be that these graphic analogies captured the students' attention more effectively, and that they provided an overall structure, by which individual concepts could be interrelated, serving as a type of organizer.

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I. INTRODUCTION

Cognitive strategies for inducing deep processing of subject matter during acquisition are of great current interest. There are many issues involved in developing, teaching, and using these kinds of cognitive strategies that are yet to be resolved, although it is to be expected that the current strong interest, accompanied by the increasing number of studies, will result in clarification of many of these issues. One of the fundamental problems is control over length of time material is processed (Faw and Waller, 1976). In situations where time available for learning is limited, efficiency of learning is important. Cognitive strategies that add substantial processing time to acquisition coding would have to be justified on other grounds; that they so increased the availability of the information to retrieval that the extra processing time was worthwhile, or that they resulted in much longer retention, or that they resulted in unusual retrieval phenomena, such as hypermnesia, (Erdelyi, Finkelstein, Herrell, Miller, and Thomas, 1976).

This study is the last of a series. In earlier studies (Rigney and Lutz, 1976a, 1976b) the effects of experimenter-supplied interactive graphic analogies during acquisition, and of student-reconstructed graphic analogies during review were explored, using a lesson in electrochemistry. In the study reported here, three processing strategies; paraphrasing, drawing diagrams, and producing verbal analogies, were used to augment acquisition coding during learning of concepts in this lesson. Since reading the item and then elaborating it using one of the above three strategies takes more time than just reading it, time spent in processing becomes an issue. Approximately equal time to process must be provided to the comparison group.

Elaboration strategies should facilitate acquisition of knowledge by helping the student establish relationships between existing knowledge and the new concepts to be learned. Paraphrasing should force the student to describe the concept in his own words, a form of active processing that might result in better retention. Drawing illustrations of concepts should force translation from the perceived verbal description into an idiosyncratic graphic form. Requiring the student to think of verbal analogies for verbally described concepts in the lesson should result in the formulation of relationships between his or her existing world knowledge and the concepts in the lesson. The analogy condition should induce deeper processing than the paraphrase or illustration strategies, since those two strategies are concerned more with transformation of form than of content. Some representative studies in the literature, relevant to these assumptions, are reviewed below.

Student-generated Illustration. Research indicates that subject-generated pictures facilitate word recognition, paired-associates learning, story comprehension, and new concept learning. Studies pertaining to the latter two categories are most relevant to the task in this study and are discussed in this section.

College students who had to illustrate prose passages performed better on a criterion test than a control group (Snowman and Cunningham, 1975).

However, students in the drawing condition spent more time than the control group. Dansereau, et al., (1975) also found that learner illustrations facilitated retention in college students, relative to a read only control. Illustrating a prose passage after reading the entire passage also facilitated retention in a study by Lesgold, Levin, Shimron, and Guttman (1975) with college students. The passages varied from abstract to concrete. A five-minute illustration interval after each passage aided recall of information for all passages. However, group differences disappeared on the delayed retention test given one week later.

In a study by Rasco, Tennyson, and Boutwell (1975), fifth-grade students remembered more about a passage on arithmetic concepts when they drew pictures to illustrate these concepts. Lesgold, McCormick, and Golinkoff (1975) trained children to portray every picturable fact from a passage while control group students were trained to read passages and answer multiple-choice questions. Instructions to use mental imagery while reading the verbal material tested in the study aided recall for illustration-training participants but not for control subjects. Although the children did not illustrate the material to be recalled during the experiment, previous illustration training may have affected the way they organized and stored information from the passage. The authors proposed that the students learned to maintain "important aspects of passage content in working or long-term memory as they read."

Student-generated Analogy. The value of generating both verbal and visual analogies is emphasized in a creativity training program by William Gordon (1961) who used the techniques of personal analogy, direct analogy, symbolic analogy, and fantasy analogy. Personal analogy, for example, requires an individual's empathetic identification with the situation under contemplation until "new visual images grow out of the identification process." His students achieved positive results by using these techniques to understand difficult concepts in science (Gordon, 1965).

Larkin and Reif (1976) trained college students in introductory physics to compare and to contrast new material with prior knowledge in the quantitative sciences, and found that students with this training learned more from new instructional material in physics and also remembered more about a passage on concepts in accounting.

Bartlett (1932) claimed that humans try to achieve meaning or understanding by attempting "to connect something that is given with something other than itself." He proposed that knowledge consists of constructive, transformational "schemata" that allow flexibility, adaptability, and economy in learning and thinking. Existing knowledge structures in the form of schemata can be used efficiently to encode new, unfamiliar information.

Davidson (1976), sees analogies as the process of cognitive transformation or "hypostatization" in which complex or abstract information is transformed into forms that are more comprehensible. The process involves actively building analogies and metaphors to understand new information. Davidson pointed out that interpreting new, complex information in terms of familiar structures may be efficient but can also lead to over-simplification, over-generalization, reification, and importation of information. In other words, analogies can be carried too far.

Student-generated Paraphrasing. Summaries are a form of paraphrase. They are concerned with larger blocks of text, in some cases, than the type of paraphrasing required of students in the present study. Paraphrasing that takes place after the entire lesson or text passage has been read would be considered to be a type of review strategy. In the present study, the paraphrasing was done immediately after reading each item, and could be classified, according to current practice, as a retention strategy, designed to facilitate storage in long-term memory (Aaronson, 1976).

An early study of learner behaviors by Arnold (1942) tested the usefulness of precis writing in learning history. He found that requiring the learner to write a summary that included the main points of a history lesson did not facilitate retention. A more recent study, however, found that writing or hearing a summary may aid learning. Ross and DiVesta (1977) found that college students benefited from experimenter-provided and from subject-generated summaries of an instructional passage in social studies, relative to a non-review control group. Students who gave an oral review following the passage had higher scores on a short-answer (constructed-response) test, but not on a multiple-choice test, than students who listened to an oral summary. The authors concluded that the subject-generated strategy elicited deeper level processing, thereby resulting in greater accessibility of the information.

A facilitative effect for subject-generated summaries was also found with children in a recent study by Doctorow, Wittrock, and Marks (1976). Reading comprehension by sixth-graders was improved when they were required to generate a summary or topic sentence for each paragraph of study.

The stories were versions of commercially published reading materials in which each paragraph in some conditions was preceded by a one or two word advance organizer. The advance organizers facilitated comprehension both with and without the summary writing condition. However, recall of story facts was best when the two treatments were combined so that students used the paragraph headings to generate their summary sentences for each paragraph.

The facilitative effect for summaries was not confirmed in a study with children by DeRose (1976) that investigated learning instructional material rather than story comprehension as in the Doctorow, et al., study. Both experimenter-provided and subject-generated summaries after every paragraph failed to aid retention of new concepts in social studies by fifth-graders. However, the means for the experimenter-provided summary groups at two levels of reading ability were higher than the mean retention scores for the subject-generated summary groups. This trend is opposite to the findings by Ross and DiVesta that college students benefit more from generating their own summary than observing someone else's summary. In fact, students in the DeRose study who were asked to generate summaries for the paragraphs had lower mean retention scores than the read-only control.

Students who paraphrased sentences in a passage remembered more from the passage than students who merely read or copied the sentences verbatim (Pio and Andre, 1977). The first of two studies demonstrated that college students who paraphrased highlighted sentences in a passage did better than students who only read the passages containing the sentences highlighted by a yellow marker. The control group in the second study read the passages and then copied the highlighted sentences while the treatment group paraphrased the highlighted sentences. Superior performance by the treatment group on test items that were related to highlighted sentence content suggests that paraphrasing involved a deeper level of processing than copying.

II. DESCRIPTION OF THE STUDY

In this study, the lesson in electrochemistry used in earlier studies in this series was used to investigate the effectiveness of three strategies: paraphrasing, illustrating, and writing analogies, relative to two reading passes through the lesson which required approximately the same amount of time.

Method

Subjects. Ninety-six undergraduate college students in an introductory psychology course chose to participate in this experiment to fulfill a course requirement. These students were randomly assigned to treatments to yield four groups of 24 students each. Males and females were rather evenly distributed among the groups.

Procedures. Prior to studying the instructional material, students in the treatment groups were instructed in how to use a specified learning strategy after reading each passage; either paraphrasing, analogy writing, or drawing diagrams. Each group was shown a sample paragraph on the topic of Computer-Assisted Instruction and then was shown a sample production of the specified strategy. For example, the students directed to write analogies were shown the CAI passage along with an analogy of CAI to television, including a few statements about their similarities and differences. Students in the control condition were told only to read the passage on CAI.

A PLATO IV computer terminal presented the instructional lesson. The computer terminal was equipped with a keyboard to allow typing responses and a touch panel to allow screen touching responses, as well as a random access audio device, so that auditory directions could be given to the students in the treatment conditions. Each main concept was introduced by a written description or definition followed by a verbal expansion. The student interacted with the lesson by touching the key concept term, which was underlined in each initial statement of that concept.

After reading the description and verbal expansion of each concept, the students in the three treatment conditions were instructed via earphones to paraphrase the passage, to draw a picture representing it, or to write a verbal analogy for it in a notebook. A period of fifty seconds was allowed for each production. The students then were told to put down their pencils and look back at the display screen for the next message. The control group was required to work through the lesson twice, to give them approximately equal exposure time to its contents. Repeating the lesson also could result in better retention. The student reading material for the second time may understand concepts that were confusing or unlearned during the first pass.

Dependent and Other Measures. A verbal multiple-choice test and a graphic recognition test were used to measure retention. The multiple-choice test consisted of 60 items in a revised version of the criterion-referenced test described earlier (Rigney and Lutz, 1975). The test consisted of three parts, each containing 20 items and corresponding to one of three levels of learning outcomes: knowledge, comprehension, and application (Bloom, 1976). The graphic test consisted of 27 items concerned with labels, features, and functions of the battery. Students' attitudes toward the PLATO terminal and toward the instructional session were assessed by semantic differential scales described earlier (Rigney and Lutz, 1976b). Several individual difference measures included a knowledge pretest and the sex of the participant.

Results and Discussion

Retention Tests. A one-way analysis of variance revealed no differences among means of either the graphic test or the multiple-choice retention test. The means are presented in Table 1. (All tables are in the Appendix). Thus, the three experimental elaboration strategies were no more effective than the simpler strategy of repeating the lesson, within the same amount of time.

Other Measures. The means of other dependent measures and individual difference measures are presented in Table 2. The groups did not differ in terms of total time spent with the task. The groups also were equivalent on the variables of pretest scores and attitudes. The students' elaboration productions were scored for following directions and for accuracy. For example, in the illustration treatment, each of the 22 productions had to be a picture that depicted the passage content. One point was given for each production judged by a graduate assistant to be accurate and appropriate. The paraphrase and illustrate treatment groups scored close to the maximum of 22, with small standard deviations. The low mean and high variance of the analogy group indicates that students in that group had difficulty in performing their task.

Tables 3, 4, and 5 present the correlations among all variables for each of the treatment groups. Correlations between the production scores for all the treatment groups and the retention posttests were quite low and non-significant. The paraphrase and illustration treatments were so easy there was very little variance in the production scores. The analogy treatment evidently was so difficult that the variance was essentially random.

Exploratory Analysis of Aptitude-Treatment Interactions. Students were categorized on the bases of their pretest scores as having little or no, some, or much prior knowledge related to concepts in the lesson. Means on the multiple-choice retention test for the four groups, at each level of prior knowledge, are given in Table 8. Inspection of these means suggests that only students with little or no prior knowledge benefited from the three elaboration conditions. The same pattern in the data can be seen in Table 9, which gives the corresponding mean scores on the graphic recognition test. Again, students with little or no prior knowledge of lesson concepts attained higher scores on the graphic recognition test when they performed the elaboration tasks than when they just read the lesson twice. One-way ANOVA performed on the multiple-choice test means of the four treatment conditions at this lowest level of prior knowledge, suggested a trend, $F\ (3,26) = 2.36$, $p < .10$.

In this experiment, one of the three treatments, the analogy task, was too difficult. Students were unable to do this task well as evidenced by the generally low production scores. Inspection of the productions from the paraphrase condition indicated most of the students' generations were almost verbatim replicas of passage statements. However, inspection of the productions of the illustration group indicated that most subjects did follow directions and did translate verbal passage content into analogous pictures. To explore the effects of the illustration treatment relative to the control group, a 2X2 factorial subset of the overall design was analyzed. The factors consisted of illustration vs. control and little vs. much prior knowledge, omitting the middle knowledge group (Table 8).

The results of the 2X2 ANOVA are given in Table 10. The analysis indicates that prior knowledge and type of elaboration task interacted, $F\ (1,17) = 6.49$, $p < .05$. Students with little or no prior knowledge learned more when they had to illustrate the important concepts of the lesson rather than just read and repeat the lesson. When the students had prior knowledge of the subject matter, however, the type of task had no effect. Including the paraphrase treatment group in this analysis (3X2) again suggests an interaction between prior knowledge and task, $F\ (2,31) = 2.91$, $p < .07$. Both the paraphrase and illustration groups did better than the control group at the lower level of prior knowledge but the type of task did not affect learning when the students were more familiar with the topic. Although it is plausible that students who have much to learn can benefit from an elaboration strategy more than students who already know the information, the study should be replicated without the analogy condition and with students pre-assigned to treatments on the basis of prior knowledge, for a more reliable test of the prior knowledge by task interaction.

Another ATI occurred between attitude toward the lesson and ability. Students who scored well on the math section of the SAT liked the analogy but not the paraphrase condition (r = .79 and -.53, respectively).

This apparent interaction between ability and treatment condition was statistically analyzed by testing the assumption of the equality of regression slopes. Ability should relate to attitude similarly in all treatments, but this assumption was violated, $\underline{F}$ (3, 49) = 4.25, $\underline{p} < .01$. Table 11 presents the ANCOVA summary table for this analysis. Correlations between ability and attitude for the Control, Paraphrase, Analogy, and Illustration groups are .19, -.53, .79, and .25 respectively (from Tables 4 through 7). It appears that high ability students liked the analogy treatment best,possibly because it is the most challenging task, and disliked the paraphrase condition, possibly because it was like a copying task.

The ATI between ability and treatment affected learning as well as attitude. The correlations between ability scores (SAT: Math) and graphic test scores were .72, -.24, .45, and .41 for the Control, Paraphrase, Analogy, and Illustration groups respectively. The assumption of equal slopes between these treatment cells was again not upheld, $\underline{F}$ (3,50) = 3.04, $\underline{p} < .05$. Table 12 presents the ANACOVA summary table. Ability influenced learning most directly in the control condition but was inversely related to learning in the paraphrase condition. Ability should positively correlate with learning in any learning situation. The fact that it did not suggests that the effects of ability were masked by another variable, possibly by attitude. Perhaps, students of high ability so disliked the paraphrase treatment that they failed to learn as much from it as from the control condition.

III. DISCUSSION

The three elaboration strategies studied here were no more effective than repetition of the lesson in the same time period. The high means and low variances for the paraphrase and illustration productions precluded substantial correlations with other variables. The relatively low mean and large variance of the analogy production scores suggests that many students had difficulty with this elaboration strategy. Students were given 50 seconds to think of an analogy for the concept described in each item. This may have been insufficient time. Perhaps, if students had been given more practice in doing this type of elaboration, before the lesson, they could have used it more effectively during the lesson. But, this would have required that more total student time be devoted to this particular strategy than to the others.

Post hoc analysis of the data suggests that elaboration strategies are more beneficial when students have little or no prior knowledge of the subject matter.

IV. SUMMARY

This is the last of a series of studies of experimenter and student supplied cognitive strategies for acquisition and retention of concepts in science. A lesson in electrochemistry was used as the subject matter in these studies. The conclusions we believe are warranted by the results of these studies as follows. The most effective strategy for facilitating acquisition consisted of experimenter-supplied, interactive graphic analogies that supplemented verbal description, in comparison to additional verbal explanation. Two explanations for these positive effects would be that these graphic analogies captured the students' attention more effectively, and that they provided an overall structure, by which individual concepts could be interrelated, serving as a type of organizer.

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V. APPENDIX

Tables

Table 1

Means and Standard Deviations of Learning Measures

Group[a]	Multiple Choice[b]	Graphic Retention[c]
Control		
Mean	34.04	14.38
SD	11.76	6.41
Paraphrase		
Mean	34.58	14.67
SD	8.29	5.46
Analogy		
Mean	34.63	14.42
SD	9.28	5.61
Illustration		
Mean	35.58	15.08
SD	6.77	4.20

[a] $n = 24$.

[b] Maximum Score = 60.

[c] Maximum Score = 27.

Table 2

Means and Standard Deviations of Other Measures

Variable	Control	Group[a] Paraphrase	Analogy	Illustration
Lesson Time (min)				
Mean	31.52	31.13	31.65	31.93
SD	3.18	2.10	3.31	3.24
Attitude Toward Lesson				
Mean	19.25	19.44[b]	18.22[b]	20.78[b]
SD	8.01	7.28	7.93	7.92
Attitude Toward PLATO				
Mean	25.92	26.78[b]	26.22[b]	26.65[b]
SD	6.91	7.30	6.16	6.73
Production Scores[c]				
Mean	---	20.79	9.13	19.48
SD	---	1.25	9.32	3.06
Prior Knowledge				
Mean	1.54	1.33	2.00	1.29
SD	1.47	1.61	1.93	1.30

[a]*n* = 24.

[b]*n* = 23.

[c]maximum score = 22.

Table 3

Correlation Matrix for Combined Group

Variable		A	B	C	D	E	F	G
A	Sex							
B	Graphic Recognition	30*						
C	Multiple-choice	30*	75*					
D	Lesson Time	-06	-11	-03				
E	Pretest	36*	52*	59*	-17			
F	Attitude Toward[a] Lesson	17	34*	42*	00	35*		

Note. n = 96.

* $p < .05$.

Table 4

Correlation Matrix for Control Group

Variable		A	B	C	D	E	F
A	Sex						
B	Graphic Recognition	28					
C	Multiple-choice	29	86*				
D	Lesson Time	13	-02	03			
E	Pretest	29	54*	65*	-13		
F	Attitude Toward Lesson	22	32	37	09	54*	
G	SAT: Verbal[a]	33	68*	66*	53	34	05
H	SAT: Math[a]	74*	72*	65*	34	39	19

Note. _n_ = 24 except as indicated.

* $p < .05$.

a, _n_ = 14.

Table 5

Correlation Matrix for Paraphrase Treatment Group

Variable		A	B	C	D	E	F	G
A	Sex							
B	Graphic Recognition	35						
C	Multiple-choice	36	75*					
D	Lesson Time	-26	-02	-26				
E	Pretest	47*	62*	70*	-24			
F	Production Score	01	33	37	-07	27		
G	Attitude Toward[a] Lesson	16	29	44*	-09	28	-17	
H	SAT: verbal[b]	-59*	19	-14	-08	-03	04	-04
I	SAT: math[b]	-14	-24	-11	-06	05	-14	-53

Note. _n_ = 24 except as indicated.

* $p < .05$.

a, _n_ = 23.

b, _n_ = 14.

Table 6

Correlation Matrix for Analogy Treatment Group

Variable		A	B	C	D	E	F	G
A	Sex							
B	Graphic Recognition	25						
C	Multiple-choice	32	63*					
D	Lesson Time	-11	-18	-23				
E	Pretest	28	46*	59*	-08			
F	Production Score	25	33	11	07	11		
G	Attitude Toward[a] Lesson	31	46*	56*	-17	49*	14	
H	SAT: Verbal[b]	62*	10	25	08	33	42	54*[c]
I	SAT: Math[b]	40	45	42	-33	63*	28	79*[c]

Note. _n_ = 24 except as indicated.

* $p < .05$.

a, _n_ = 23.

b, _n_ = 15.

c, _n_ = 14.

Table 7

Correlation Matrix for Illustration Treatment Group

Variable		A	B	C	D	E	F	G
A	Sex							
B	Graphic Recognition	43*						
C	Multiple-choice	32	66*					
D	Lesson Time	-11	-03	31				
E	Pretest	38	61*	46*	-34			
F	Production Score[a]	-07	-06	04	16	-34		
G	Attitude Toward[a] Lesson	11	27	31	13	13	08	
H	SAT: Verbal[b]	47	25	32	08	-12	37	41
I	SAT: Math[b]	72*	41	34	-52	54*	-46	25

Note. n = 24 except as indicated.

* $p < .05$.

a, n = 23.

b, n = 15.

Table 8

Means and Standard Deviations of
Multiple-Choice Retention Test Scores

Prior Knowledge		Control	Paraphrase	Analogy	Illustration
		Treatment Condition			
Little	$\bar{X}$	22.67	29.82	27.00	29.86
	SD	3.56	6.26	6.29	6.31
		n=6	n=11	n=6	n=7
Some	$\bar{X}$	35.46	35.00	33.10	37.71
	SD	11.79	6.07	7.92	6.07
		n=13	n=8	n=10	n=14
Much	$\bar{X}$	44.00	44.40	42.25	39.00
	SD	6.16	7.02	7.36	2.00
		n=5	n=5	n=8	n=3

Table 9

Means and Standard Deviations of Graphic Recognition Test Scores

Prior Knowledge		Control	Paraphrase	Analogy	Illustration
		Treatment Condition			
Little	$\overline{X}$	7.83	11.46	11.67	12.14
	SD	2.14	3.83	4.55	4.30
		n=6	n=11	n=6	n=7
Some	$\overline{X}$	15.69	16.13	12.30	15.36
	SD	6.18	4.67	4.86	3.13
		n=13	n=8	n=10	n=14
Much	$\overline{X}$	18.80	19.04	19.13	20.67
	SD	4.66	6.06	4.49	2.52
		n=5	n=5	n=8	n=3

Table 10

ANOVA Summary Table for
Multiple-Choice Test

Source	df	M.S.	F	P
Task	1	5.69	.21	NS
Prior Knowledge	1	1101.52	40.53	.01
Task x Knowledge	1	173.30	6.49	.02
Error	17	27.18		

Table 11

ANCOVA Summary Table for
Attitude toward Treatment

Source	df	M.S.	F	p
Task	3	49.99	.81	NS
SAT: Math	1	121.30	1.97	NS
Error	52	61.57		
Equal slopes (task x SAT)	3	220.32	4.25	.01
Error	49	51.85		

Table 12

ANCOVA Summary Table for
Graphic Learning Test

Source	df	M.S.	F	p
Task	3	12.03	.53	NS
SAT: Math	1	237.87	10.42	.01
Error	53	22.83		
Equal slopes (task x SAT)	3	62.26	3.04	.05
Error	50	20.47		

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